Distributed at
8/8/91 meeting
in Trenton

EPA Robert S. Kerr Research Laboratory

Two Research Projects on Aerobic Biodegradation

Bioventing

EPA has conducted a pilot-scale field testing of "bioventing" at a jet fuel spill site. This research is described in the fact sheet transmitted with Don Kampbell's June 27, 1991 memo. The technology was successful in bioremediating volatile organics in unsaturated soils at the jet fuel spill site. However, its effectiveness for treating semivolatiles such as diethlyl hexyl phthalate has not been determined. According to Dr. Kampbell, biodegradation may not occur in soils which contain high concentrations of volatile organics because the soil contamination is toxic to microorganisms. Bioventing may overcome this problem by venting the volatiles from the hot zone via an injected air stream to a soil zone where conditions are more amenable to biodegradation. The organics are desorbed from the air stream in this zone, where biodegradation is believed to take place. Water and nutrients are applied at the surface to enhance the process. Further research on bioventing is planned.

Field Methods to Estimate the Rate of Aerobic Bioremediation

Dr. Kampbell is also conducting a two year research project entitled "Field Methods to Estimate the Rate of Aerobic Bioremediation" to develop methods to determine whether bioremediation is occurring at a site. Three tests are involved:

- dehydrogenase activity, which is related to the quantity of active biomass,
- intrinsic rate of oxygen consumption, and
- organic pollutant degradation, which is determined by measuring changes in pollutant concentration over time.

Soil moisture content and nutrient content may be adjusted, if necessary, prior to the testing. The raw materials which are tested are samples taken from vertical profile soil core samples. Each vertical foot of soil is generally collected as a separate sample. The testing for a set of samples is expected to take about two months.

Dr. Kampbell has requested soil samples from the L.E. Carpenter site for use in this research project. He has recommended that vertical core samples be collected at four locations from the surface to the top of the water table (or to the top of the floating organic layer, if applicable). Each foot of core sample would be used to produce an individual sample of approximately one pint.

Dr. Kampbell has stated that the results for a set of samples could be released when that set of samples has been evaluated, as opposed to at the end of the two year study.

This fact sheet prepared on 8/7/91 by Jonathan Josephs, Project Manager, based on conversations with Dr. Don Kampbell.

Received 7/22/91

HIGHLIGHTS - RSKERL,Ada

A two year research project entitled "Field Methods to Estimate the Rate of Aerobic Bioremediation" will be conducted by Drs. Don Kampbell and John Wilson as part of an interagency agreement between USAF/ESC/Tyndall AFB and USEPA. Simple field tests will be developed to determine if a spill site has accliminated and is undergoing bioremediation. The approach will be to measure dehydrogenase activity, intrinsic rate of oxygen consumption, and organic pollutants degradation in vertical profile core samples. The assay techniques will be used to characterize spill sites and monitor field bioremediation systems.

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June 27, 1991

MEMORANDUM

SUBJECT: Bioventing Research Project

FROM: Don Kampbell, Research Chemist DK
Subsurface Processes Branch

TO: Jon Josephs
EPA Region II

Enclosed is a copy of a recent report I prepared for my bioventing research project. The report is on two pilot-scale systems that I would like to expand to a full-scale system. If you are interested in doing something together, let me know. I am also starting a new research project named "Field Methods to Estimate the Rate of Aerobic Bioremediation." Your site that we discussed might be one that I could use as a source of soil or core samples to evaluate my methods. Anyway, contact me if we can do work jointly.

Enclosure

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SUBSURFACE REMEDIATION AT A GASOLINE SPILL SITE USING A BIOVENT APPROACH

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INTRODUCTION

Soil vapor extraction in combination with biodegradation is a promising remediation technology. Laboratory treatability studies have shown that the process of bioventing should be adaptable to a considerable range of conditions and volatile organics.

An aviation gasoline spill of about 35000 gallons occurred at an air station in 1969. A major portion of the spill still persists as oily phase residue in the capillary fringe of the subsurface. The vertical profile of the subsurface is a relatively uniform beach sand to below the water table which was near 5 meters.

The objective of the project was to design, install, operate, and evaluate two pilot-scale bioventing systems. Anticipated results were to demonstrate the enhanced feasibility of engineered biological remediation of a subsurface containing retained oily phase gasoline. Performance of the two pilot-scale systems was to demonstrate that surface emissions of fuel are minimum, total fuel hydrocarbons in remediated core material will be less than 100mg/Kg, final benzene in the underlying groundwater will not exceed 5µg/L, remediation will be completed in a reasonable time, and the technique is applicable to full-scale reclimation.

EXPERIMENTAL

Prior to design of the bioventing units several laboratory soil microcosm treatability studies were conducted using surface soil from the field site. Aviation gasoline vapor biodegradation was rapid and complete showing curves typical of first-order kinetics.

Degradation occurred at all temperatures within a range of 4 to 37°C. A moisture range of 3.5 to 20 percent did not limit degradation. Reaction rates and active biomass were increased at least four fold in test microcosms receiving a nutrient addition of nitrogen, phosphorus, and potassium. The biodegradation rates obtained from acclimated soil microcosms were more than adequate to consume all vapors in the unsaturated zone at the pilot-scale demonstration site.

DESIGN

The design concept provided subsurface forced aeration to vaporize and transport oily phase components upward to more amiable microbial degradation activity. A surface area above the plume was divided into two adjacent equal plots of 13.7 X 22.9 meters (45 X 75 feet). The north plot shown in Figure 1 was an injection only aeration system. The injection wells were placed in a 3 X 5 grid 3.05 meters apart to a depth of 5.5 meters which was one meter below the existing water table level. Each well had an outer 5 inch diameter PVC tube with a well screen of 10 vertical slots 1.5 meters long. A depth adjustable inner 4 inch diameter open-end PVC tube 5.8 meter long with a lower rubber packer and an upper rubber collar seal was inside the larger well tube. The above ground portion of the smaller tube was connected to a main forced air transfer line. An injection depth was set to emit air flow over 0.15 meter depth just above the water table. Seven vapor withdrawal wells were similar in construction to the injection wells and placed alternately in the south plot. Extracted air was reinjected to a depth of 4 meters midway between coupled units as shown in Figure 1. A blower flow rate of 5 cfm per plot was used which was equivalent to a calculated forced air residence time of 24 hours.

A nutrient solution of 25, 5, and 2 mg/Kg soil of nitrogen, phosphorus, and potassium was applied throughout the unsaturated zone to sustain microbial activity. A turf grass cover was established and maintained to provide a root zone rhizosphere to complete removal of fuel vapor constituents in surface emissions.

SYSTEM MONITORING

Core material, underlying groundwater, soil gas and air vented air streams were monitored to determine the extent of remediation.

Vertical profile core samples were collected and analyzed for fuel carbon at three month intervals. Groundwater was analyzed monthly for BTEX, dissolved oxygen, and nutrients. Soil gas probes were installed to measure fuel vapor, oxygen, and carbon dioxide on a regularly scheduled basis. Subsurface moisture and temperature was recorded from the meter readings. Soil pore water was collected from different depths for nutrient analysis. Gauge readings were recorded for flow and pressure of the vented air streams. Surface emission samples were collected by cartridge traps for analysis of vapor constituents.

RESULTS

The air blowers were turned on during October 1990. They were operated continuously for three months at a subsurface volume flow calculated to be a 24 hour residence time. The systems were shut down for the winter in January. The frost line was then below the turf root zone.

Soil gas was monitored at depths of 1, 2, 3, and 4 meters. Fuel vapor concentrations increased to a maximum the first few days at all depths in both the north and south plots then decreased rapidly until stabilizing in three weeks (Figures 2, 3). A combustible gas Threshold Limit Meter(TLV) was used. A response factor near 0.6 was obtained from aviation gasoline vapor when comparing meter readings with standard calibration by butane in ppm(v/v). Initial carbon dioxide in the subsurface soil gas varied from 3.5 to 8.0 percent. During venting the levels remained at <0.1 percent. Oxygen initially was in the 10 to 14 percent range then increased to 20 percent during venting.

Water from the three monitoring wells was collected at two depths and analyzed as shown in Table 1. Benzene at depths nearest to the water table within the influence of forced air venting was much lower than at depths further down.

Averaged concentrations of fuel carbon over vertical profiles of both the north and south plots showed much greater reductions than in adjacent control locations (Tables 2,3). Although fuel carbon had been reduced considerably, the desired concentration of 100mg/Kg has not yet been attained.

Surface emissions were less than 1μg fuel hydrocarbons/L soil air (Tables 4). The decrease of 300 fold from one meter depth to the surface suggested an active cleansing action in the turf root rhizosphere.

DISCUSSION

Operation performance of both venting systems during the first three months was satisfactory. The oily phase gasoline was reduced about 60 percent in the core profile of both bioventing system plots. The data obtained suggested that an average of <100mg/Kg over the one meter smear range can be attained in less than one year operation time. Water quality for benzene should eventually be within the 5μg/L requirement at depths near the water table. Benzene levels at lower groundwater depths will be monitored as operational time passes to determine the extent of remediation. Fuel emissions from the surface were very low compared to soil gas concentrations at a one meter depth. Emphasis during the remainder of the project period will be placed on refining sampling and analytical techniques. An attempt will also be made to locate the zone of active biodegradation occurring at the site.

ACKNOWLEDGEMENTS

Christopher J. Griffen, Project Engineer, with the TraverseGroup, Inc. was the on-site operations manager.

John T. Wilson, Bioremediation Team Leader, with the Robert S. Kerr Environmental Research Laboratory has provided helpful guidance.

Table 1

WATER QUALITY - FEBRUARY 1991

SAMPLE	DEPTH METER	TOTAL AVGAS (µg/l)	BENZENE (µg/l)
Upgradient	5.3	3090	182
Upgradient	6.7	415	132
South Plot	5.2	686	<1
South Plot	6.1	1680	19
North Plot	5.1	2790	7
North Plot	6.4	2410	202

Table 2

CORE PROFILE OF FUEL CARBON, mg/kg

DEPTH CENTIMETERS	CONTROL$_1$ SEPT. 1990	CONTROL$_1$ FEB. 1991	NORTH PLOT SEPT. 1990	NORTH PLOT FEB. 1991
406	234	97	52	<8
444	461	1080	923	18
462	1030	1000	1253	153
488	701	731	926	972
503	6500	8240	6740	1420
523	5620	3020	5780	2200
538	N.D.	<8	39	53
$\bar{X}$	2862 →	2814	3124 →	953 ↓
				100

Table 3
CORE PROFILE OF FUEL CARBON, mg/kg

DEPTH	CONTROL$_2$		SOUTH PLOT	
CENTIMETERS	SEPT. 1990	FEB. 1991	SEPT. 1990	FEB. 1991
406	<8	<8	11	<8
444	193	84	144	16
462	238	85	253	70
488	212	140	1970	946
503	549	639	1880	1860
523	34	10	2830	17
538	<8	<8	<8	<8
$\bar{X}$	245 →	192	1415 →	582 ↓
				100

Table 4

SURFACE EMISSIONS
Volatile Hydrocarbons

Nov. & Dec.	South Plot	North Plot
Canopy	0.24 µg/L	0.52 µg/L
One meter probe	271 µg/L	174 µg/L
Per cent removed	99.9	99.7

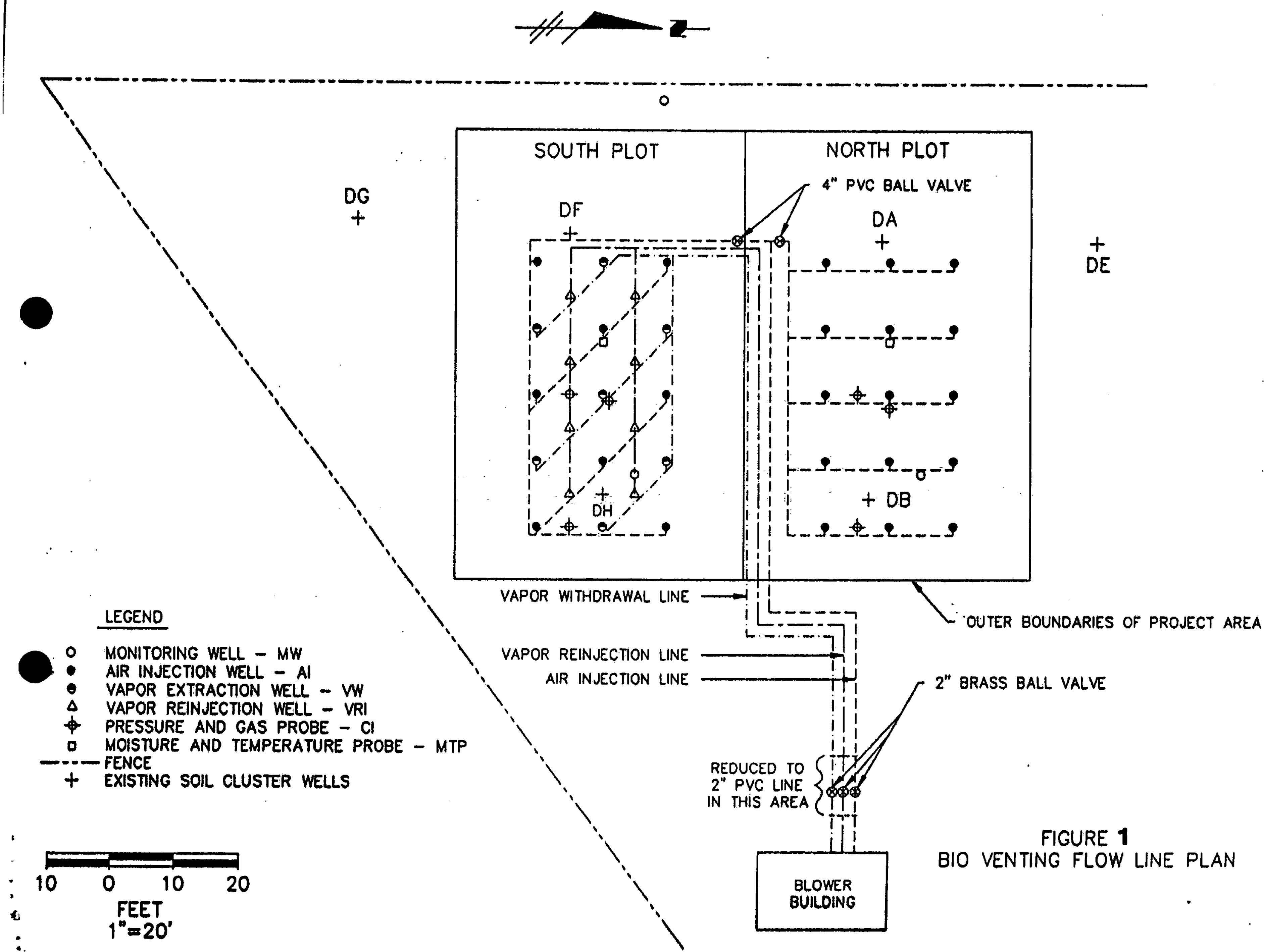

FIGURE 1
BIO VENTING FLOW LINE PLAN

Figure 2

TLV vs. Time for the North Plot

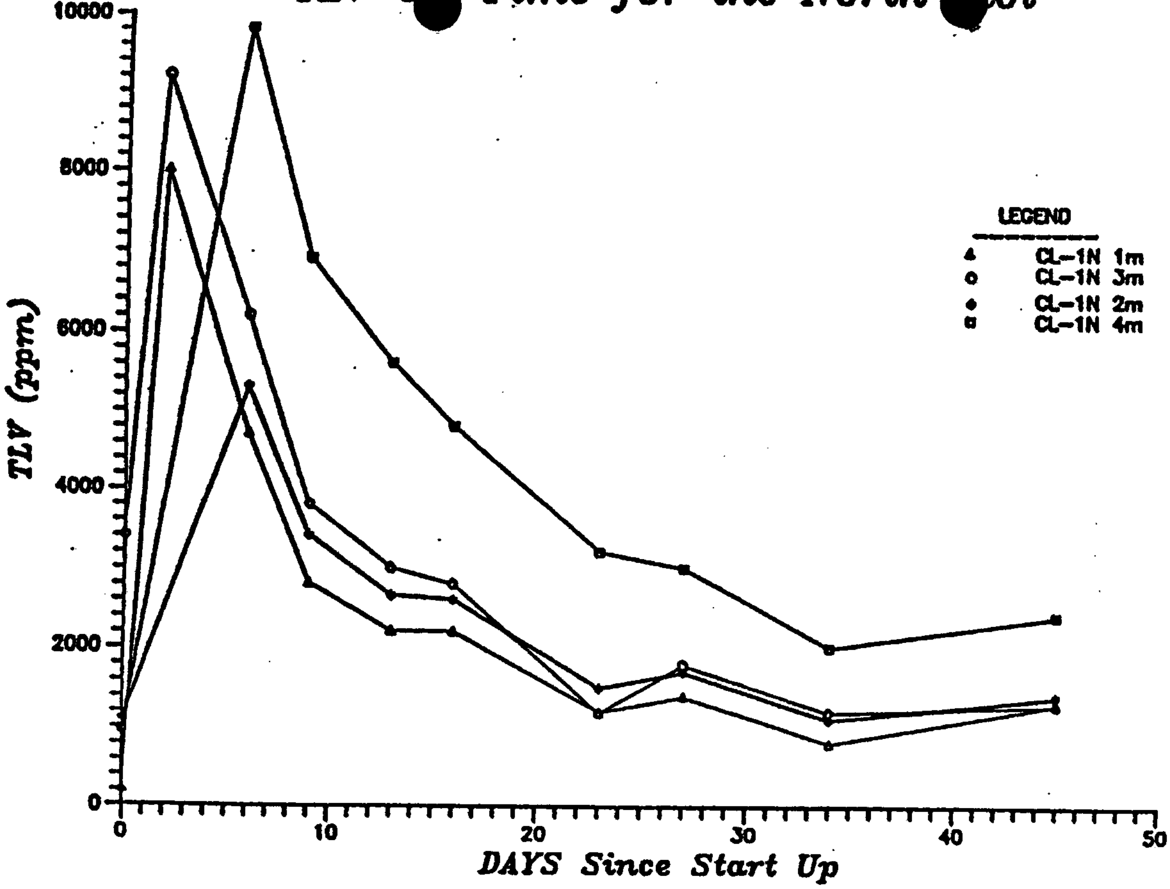

Figure 3

TLV vs. Time for the South Plot